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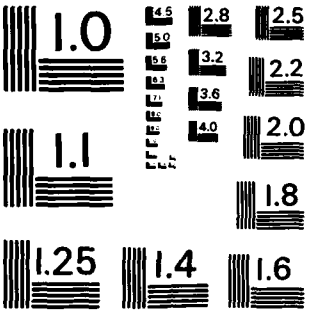

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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARD ADVISORY REPORT No.203

Technical Evaluation Report on the 46th Symposium of the Avionics Panel on Space System Applications to Tactical Operations

by

J.Statsinger

NORTH ATLANTIC TREATY ORGANIZATION

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.203

TECHNICAL EVALUATION REPORT

on the

46TH SYMPOSIUM OF THE AVIONICS PANEL

on

SPACE SYSTEM APPLICATIONS TO TACTICAL OPERATIONS

by

Mr Joseph Statsinger
The Aerospace Corporation
El Segundo, CA 90009
USA

This publication was prepared at the request of the Avionics Panel of AGARD.
The Symposium was conducted at the NATO-Secret level.

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- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
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- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
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   Mr E.D.Greinke, Scientific Advisor, SHAPE, BE

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Mr P.Kruh, The Aerospace Corporation, Los Angeles, CA, US

20. TACTICAL APPLICATIONS OF GPS USER EQUIPMENT
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Chairman: Dr R.W.Macpherson, CA

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Mr J.O.Cochran, Ford Aerospace and Communications Corporation, Sunnyvale, CA, US

SESSION VII – SUMMARY

Chairman: Mr J.Statsinger, US

EXECUTIVE SUMMARY

The following summarizes the significant observations and recommendations from the Technical Evaluation.

Observations

It was noted that a number of areas would benefit by additional effort:

1. Communication between users and developers should be improved in order to:
   (a) Establish better quantification of requirements
   (b) Expose the developers more clearly to the exigencies of battlefield applications
   (c) Identify the needs for flexibility
   (d) Improve the familiarity of the using community with space system operational characteristics
2. Steps should be taken to improve interoperability among existing and planned systems in the NATO environment in order to enhance the utility of these broadly applicable systems.
3. The participation of the various NATO nations in cooperative development and application of space systems should be increased.
4. Alternative techniques for procurement and fielding of space systems should be developed and evaluated considering that small quantities and high unit costs will continue to be characteristic of these systems.
5. The impact of retrievable boosters on the development and application of space systems should be further studied.
6. The development of suitably configured ground assets should be pursued for the purpose of assuring maximum survivability and utility.
7. Areas should be identified where further advances in technology are desirable, in order to support future systems having greater capabilities than systems currently available.
8. Future activities should stress the importance of overall systems engineering and systems macro-architecture to assure that ail of the elements involved in these complex systems are properly interfaced and that systems designs for individual space systems interact with each other for the overall greatest effectiveness in providing support to military operations.

Recommendations

1. Conduct a review of on-going and planned communication and navigation systems, both space and ground based. The review should focus on issues of interconnection and interoperability among all of these assets and the related architectural issues. The objectives should be to optimize the utility and survivability of the overall NATO capability.
2. Plan a symposium on space technology with the objective of defining initiatives which the NATO nations should pursue to increase the capability of future space systems.
3. Plan a symposium on the subject of space system macro-architecture. This should include questions of interoperability and survivability as major topics.

TECHNICAL EVALUATION REPORT

by

Joseph Statsinger
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INTRODUCTION

The 46th Symposium of the Avionics Panel was held at the H.J.E.Reid Activities Center of the NASA Langley Research Center, Hampton, Virginia, USA, 17—20 October 1983. The program chairman for the meeting was Dr Max T.Weiss of the Aerospace Corporation, El Segundo, California, USA. The papers presented and discussions conducted at the meeting are published in Conference Proceedings CP-344 and CP-344 (Supplement).

THEME AND OBJECTIVES

The advances in space technology and systems during the past two decades have led to the availability of resources which can contribute to increased combat capability and efficiency in tactical military operations. Military communications satellites such as the NATO and SKYNET series and the US COMSATS have demonstrated their effectiveness as elements of military command and control systems. The various weather satellites permit more accurate and more timely weather forecasting and have become important to all military operations. The 18 Satellite Global Positioning System which is currently under development may revolutionize weapon system navigation and guidance over the next decade.

The importance of space assets in supporting tactical operations is gradually becoming better appreciated by the leaders of the R&D community and by military leaders in the NATO countries. However, the full potential of these systems has not yet been realized. The intent of this symposium is to bring into focus and to characterize the attributes of space systems which contribute to the effectiveness of tactical military operations.

The objectives of the meeting are as follows:

- Provide an overview of tactical needs which are effectively addressed by space systems.
- Characterize the various existing and potential space systems with emphasis on those attributes which are most related to tactical needs.
- Assess the advantages and limitations of space systems in supporting combat operations.
- Investigate the interaction of space assets with ground and mobile resources and consequent operational issues.
- Discuss future trends in space technology and their relationship to evolving combat needs.

GENERAL DESCRIPTION

The program consisted of thirty-four invited papers and two round table discussions, divided into seven sessions. The quality of the material presented well reflected the experience and expertise of the authors.

The opening session consisted of presentations by very senior members of the NATO space sciences and military communities. A broad overview was presented which served as an excellent introduction to the more detailed discussions.

Space systems and their applications had not been reviewed for a number of years by AGARD. The rapid progress that has taken place in this field and the increasing role played by space systems in maintaining and supporting military effectiveness was clearly evidenced in the range and depth of the subjects discussed in the sessions which followed. The symposium made a timely contribution by stressing the current desirability of more intensive application of space systems to military operations.

TECHNICAL EVALUATION

Session I — Overview Chairman: Dr M.T.Weiss

This session provided a useful framework for the subsequent discussions. The speakers characterized the range of current and potential applications of space systems and provided a perspective on the past and a forecast of future trends.

Dr Mark described the evolution of space capabilities, the importance of military space to the maintenance of peace and the need for joint effort among the NATO nations to maximize progress in current and future developments.

General Randolph reviewed the currently operational US military space systems and gave examples of their effectiveness in crises situations. He covered the range of capabilities available and described systems currently under development to meet future needs. He suggested that cooperative efforts among the NATO countries including the US, would be of great value to the tactical community.

Mr Greinke continued this theme by describing space system applications in the NATO theater. He indicated how space systems contribute to countering the threat to NATO forces and pointed out that the full exploitation of space assets is a learning process which is not yet complete.

General Craig provided useful insights into the application of space systems to tactical aircraft. A particular point was made that the proper design of terminals for tactical aircraft applications is of great significance.

The interaction of space systems capabilities and NATO's naval needs was the subject of Mr Nahra's talk. Among the points covered were the problems involved in combining forces of the various nations and in clearly distinguishing hostile and friendly forces.

Sessions II & III — Communications

These sessions brought into focus the vigorous activity in space communication systems throughout the NATO community. Both current applications and on-going developments were addressed. Some of the major issues discussed included the need for overall architectural planning, the importance of internetting and interoperability and of suitably designed terrestrial stations to optimize system utility.

Session II Chairman: Mr D.Pichoud

Colonel Gibson described current and prospective US systems including their utility, the threats to which they must respond and prospective upgrades. The possibilities for internetting among the various space assets and with ground networks were discussed.

Mr Sondereger provided a perspective from a broad architectural point of view, showing the possibilities for fitting both current and prospective systems into an overall framework. Problems of network control and management were cited.

Dr McElroy characterized EHF systems for space applications including the current and prospective state of the art in components, the applicable types of signal structures and the advantages which this frequency regime offers to military users.

Mr Du Chéné's paper covered advanced developments for satellite communication as applied in the Syracuse system. The use of spread spectrum in the X-band frequency regime was described together with the techniques for synchronization and the parameters of both fixed and mobile ground terminals.

The problem of orbit selection is pertinent to the various NATO nations whose territory extends to high latitudes. An analysis and evaluation of alternatives was presented by General Collins. The advantages of the twelve hour elliptical orbit for high latitude application include coverage, ease of doppler correction, and lower orbital energy requirements.

Session III Chairman: Mr B.Atkinson

An overview of communication satellite activity in the United Kingdom was presented by Mr Atkinson. The discussion included description of developmental activities, testing facilities, and the various aspects of terminal equipment design important to the users. The advantages of interaction between the military and civil systems were pointed out.

Mr Tozer described the SKYNET 4 development and the details of the communication payloads functional characteristics. A description of potential advances for the next generation of SKYNET satellites was presented.

Dr Madams reviewed the communication satellite field from the viewpoint of Royal Navy requirements. A systematic presentation of requirements in matrix form was shown and a discussion of internetting as a means of enhanced survivability was presented.

Further discussion of terminal issues was furnished in a paper by Mr Law. Various types of terminals for different classes of users were described together with the variations and characteristics necessary for different classes of services.

Session IV — Navigation Chairman: Ir. H.A.T.Timmers

Discussion of space based navigation systems was initiated by Colonel Jones with an overview discussion of the GPS/Navstar program. A description was provided of the current configuration and the plans for providing a full

constellation within the next few years. A variety of user equipments are under development and accuracy demonstrations have been accomplished for a variety of host vehicles including aircraft, ships, and land vehicles.

Mr Kruh described the means of building up a GPS constellation, the orbital configuration necessary for achieving global coverage and the geometric issues associated with maintenance of accuracy. The 18 satellite final configuration will provide better than 99% coverage globally.

The techniques for system tests which have been developed and are currently used to evaluate system performance were discussed by Dr Clifford. The precision land range as well as the arrangements for naval testing were described.

For tactical aircraft applications, a large number of variables must be controlled in order to meet accuracy requirements. Captain Barbee presented a description of these items together with an evaluation of the utility of the GPS system in controlling them. In summary, the GPS system simplifies control and supports enhanced effectivenesss in a number of tactical applications.

Colonel Price reviewed the prospective utilization of Navstar by the NATO nations. Navstar development is perhaps unique in that nine NATO nations have participated in the GPS development and acquisition program. Furthermore, the intended use of Navstar by the various nations has supported improved commonality of navigation and mapping references among the nations.

Session V — Remote Sensing Chairman: Dr R.W.MacPherson

The discussion of current capabilities in remote sensing focused on meteorological satellite systems and their use. Other aspects of remote sensing were covered in Session VI.

The Defense Meteorological Satellite Program (DMSP) was presented in an overview by Colonel Curtis. The DMSP system provides worldwide strategic tactical and weather data to both fixed and mobile users. Future developments includi enhanced sensing capabilities were described.

Colonel Rauscher described the manner in which the Air Force Global Weather Central merges data from DMSP as well as other weather satellites and terrestrial and oceanographic data. Data is processed every three hours and 48 hour forecasts are furnished. Tactical uses during various crisis were cited as well as support of planned military exercises.

The civilian weather satellite system and its relationship to military systems was presented by Dr Miller. The interaction between the American civilian systems and those of other nations was discussed and the importance of cooperation between all nations to achieve accurate weather forecasts was emphasized.

The importance of space systems in support of tactical military activities was illustrated graphically by Mr Pothecary and Captain Marsh in their discussion of the Falkland Island experience. The usefulness of remotely sensed data was apparent early on, and actual experience during crises led to changes in terrestrial equipment which further enhanced the utility of space systems. Practical experience is essential to optimizing utility.

The direct application of satellite weather data via video recording, the use of false color, and other human engineering techniques was discussed by Mr Boswell. The importance of techniques to enhance interpretability was clearly demonstrated.

Further emphasis on this subject was provided by Mr Weigand. The ability to adapt to varying circumstances and a variety of user requirements was noted. The flexibility of digital techniques is important. The need to receive frequent observations under some circumstances is characteristic of certain applications.

Session VI — Prospects for the Future Chairman: Dr F.I.Diamond

The papers in this session were oriented toward discussion of those space system elements which have demonstrated their importance but have not yet achieved full operational status or application.

General Abrahamson described the space shuttle, its objectives and accomplishments and noted that a variety of upper stages are available for various applications. The ability to retrieve payloads, to assemble large space structures in orbit and, generally, to greatly increase the flexibility of the management of orbiting assets were cited. Launch capability from either coast of the US will become available. Cooperative efforts with other NATO nations were described.

The most recent initiative in regard to shuttle upper stages was presented by Mr Clark. This is the shuttle-configured Centaur upper stage which will be capable of putting approximately 13,000 lb payloads into geosynchronous orbit using liquid oxyen and liquid hydrogen propellants.

In regard to expendable launch capability, a major development has been the Ariane booster, described by Mr Brachet. The Ariane booster is under the cognizance of the European Space Agency (ESA). It consists of a family of vehicles which has a present capability of placing 1500 kilograms into a synchronous equatorial transfer orbit. The Ariane family is an evolving system which incorporates planned growth leading to an eventual 4000 kilogram capability. The Ariane has

demonstrated its performance in practical use. An additional pad is being built to provide greater launch flexibility and capability for the largest version of Ariane currently planned.

Turning from launch vehicles to future developments for spacecraft, Mr Cochran described a series of measures involved in protecting future satellites systems from possible negation. Improvements in satellite autonomy, the use of cross-linking between the various satellites and increased use of mobile terminals were discussed.

Remote sensing for applications other than weather forecasts was the subject of a discussion by Dr Velten. The European remote sensing satellite system, ERS1, is an application of imaging synthetic aperture radar to the measurement of geophysical properties including wind fields, ocean imagery and ice. The data will have both scientific and economic impact.

Another approach to the remote sensing of geophysical features and to mapping, is the SPOT remote sensing system described in a paper presented by Mr Brachet. The system is developed under the auspices of the French National Space Agency. It embodies a passive sensor operating in three visible bands and the near infra-red. Among its applications are evaluation of natural resources (renewable and mineral) as well as medium scale mapping.

Further discussion of advances in synthetic aperture radar technology was presented in the paper by Mr Schotter. An advanced processor is under development which has attributes which make it particularly suitable for data processing on board spacecraft.

Passive sensing was also the subject of the paper presented by Mr McCarthy on the application of infra-red techniques to detect objects of military interest. The use of space based sensors for this purpose provide advantages in coverage and timeliness of data.

Additional discussion of the technology and application of imaging synthetic aperture radar for earth resources research was presented in the paper by Mr Monson. The Shuttle imaging radar has been used to provide radar characterization of areas of the earth which had not been previously observed by this class of sensor. A movie of some of the observations was shown.

Session VII — Summary **Chairman: Mr J.Statsinger**

This session was structured to provide a recapitulation and summary of ideas and issues which developed from the papers and discussions of the preceding six sessions. Participants for this session included the chairmen of the preceding sessions, or their representatives, as well as Dr Allen Stubberud, Chief Scientist of the US Air Force. Some introductory remarks were presented by Mr Joseph Statsinger, vice chairman of the Program Committee.

The remarks and discussions during this session generally covered the major issues in regard to space system applications. Substantially all of the material from this session related to assessments, observations and recommendations with regard to the symposium topics. The executive summary, as well as the next section of this report covering these matters is, in substance, a recapitulation of Session VII.

ASSESSMENT

It was the general consensus that the symposium material was significant and relevant to the intent of the symposium and that the objectives of the meeting as outlined in the Theme and Objectives were indeed met. In addition, the material presented went beyond the objectives of the meeting and provided important insights into additional aspects of space systems and their military applications.

With regard to the stated objectives of the meeting:

The papers and discussions presented indicated the importance of space systems in meeting current and future tactical needs in communication, navigation, surveillance, remote sensing and weather.

The characterization of space systems was accomplished with clarity and focused well on the relationships between the systems and their tactical application.

The advantages and limitations of space systems in tactical applications were reviewed in conjunction with the interaction of terrestrial resources and space resources.

A significant number of trends for the future and their importance in military applications were discussed.

OBSERVATIONS

It was noted that a number of areas would benefit by additional effort:

1. Communication between users and developers should be improved in order to:
   (a) Establish better quantification of requirements
   (b) Expose the developers more clearly to the exigencies of battlefield applications

(c) Identify the needs for flexibility

(d) Improve the familiarity of the using community with space system operational characteristics.

2. Steps should be taken to improve interoperability among existing and planned systems in the NATO environment in order to enhance the utility of these broadly applicable systems.

3. The participation of the various NATO nations in cooperative development and application of space systems should be increased.

4. Alternative techniques for procurement and fielding of space systems should be developed and evaluated considering that small quantities and high unit costs will continue to be characteristic of these systems.

5. The impact of retrievable boosters on the development and application of space systems should be further studied.

6. The development of suitably configured ground assets should be pursued for the purpose of assuring maximum survivability and utility.

7. Areas should be identified where further advances in technology are desirable, in order to support future systems having greater capabilities than systems currently available.

8. Future activities should stress the importance of overall systems engineering and systems macro-architecture to assure that all of the elements involved in these complex systems are properly interfaced and that systems designs for individual space systems interact with each other for the overall greatest effectiveness in providing support to military operations.

RECOMMENDATIONS

1. Conduct a review of on-going and planned communication and navigation systems, both space and ground based. The review should focus on issues of interconnection and interoperability among all of these assets and the related architectural issues. The objectives should be to optimize the utility and survivability of the overall NATO capability.

2. Plan a symposium on space technology with the objective of defining initiatives which the NATO nations should pursue to increase the capability of future space systems.

3. Plan a symposium on the subject of space system macro-architecture. This should include questions of interoperability and survivability as major topics.

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14. Abstract

This ~~Technical Evaluation~~ Report, based on the NATO Secret AGARD Avionics Panel Symposium on Space System Applications to Tactical Operations, summarizes the 34 papers presented, summarizes the discussion sessions, draws conclusions and makes recommendations. Unclassified papers and abstracts for this Symposium are contained in AGARD-CP-344. Classified papers, discussions and round table discussions are contained in AGARD-CP-344 (Supplement). Sessions covered an overview, communications, navigation, remote sensing, and prospects for the future.

The objectives of the symposium were ~~as follows~~:

a. Provide an overview of tactical needs which are effectively addressed by space systems;

b. Characterize the various existing and potential space systems with emphasis on those attributes which are most related to tactical needs;

c. Assess the advantages and limitations of space systems in supporting combat operations;

d. Investigate the interaction of space assets with ground and mobile resources and the consequent operational issues,

f. Discuss future trends in space technology and their relationship to evolving combat needs.

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AGARD-AR-203

Space technology
Communication satellites
Weather satellites
Global positioning system
Space systems
Satellite terminals
Remote sensing
Navigation

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TECHNICAL EVALUATION REPORT on the 46TH SYMPOSIUM OF THE AVIONICS PANEL on SPACE SYSTEM APPLICATIONS TO TACTICAL OPERATIONS
Joseph Statsinger
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The objectives of the symposium were as follows:

a. Provide an overview of tactical needs which are effectively addressed by space systems.
b. Characterize the various existing and potential space systems with emphasis on those attributes which are most related to tactical needs.
c. Assess the advantages and limitations of space systems in supporting combat operations.
d. Investigate the interaction of space assets with ground and mobile resources and the consequent operational issues.
f. Discuss future trends in space technology and their relationship to evolving combat needs.

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